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The Performance of OFDM System for (16, 32, 64) QAM Before and After Performing Clipping Technique

[1]Fadhil M. Aswad, [2]Mohammed S. Jawad and [2]Ho Yih Hwa
[1]Department of Electrical, Electronic and Systems Engineering, Faculty of Engineering and Built Environment, National University of Malaysia (UKM), 43600 Selangor, Malaysia
[2]Department of Telecommunications Engineering, Faculty of Electronic and Computer Engineering, University Technical Malaysia Melaka (UTeM), Box. 76100 Melaka, Malaysia

Abstract: Wideband communication is offered by Orthogonal Frequency Division Multiplexing (OFDM) systems due to the carrier division of many sub-carriers. Such division increases the rate of data sent from the transmitter to the receiver which is appropriate for the modern digital communication used in the latest wireless generation. Therefore, the aim of the study reported in this study is to evaluate the performance of the OFDM systems for three QAM schemes (16, 32 and 64). To achieve this, the study used a novel clipping and filtering technique to reduce the high Peak to Average Power Ratio (PAPR) issue in the OFDM systems. The findings showed that systems suffering from a drawback represented by the high PAPR, thus resulting into distorting the output signal and degrading the transmission quality.

Key words: Clipping and Filtering (CF), Peak To Average Power Ratio (PAPR), Orthogonal Frequency Division Multiplexing (OFDM), Quadrature Amplitude Modulation (QAM), drawback

INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is defined as a combination of modulation and multiplexing. Multiplexing generally refers to independent signals which are produced by different sources. So what matters is the question of how to share the spectrum with these users. In OFDM, the question of multiplexing is applied to independent signals, but these independent signals represent a sub-set of one main signal. In addition, in OFDM, the signal itself is the first split into independent channels modulated by data and then re-multiplexed to create the OFDM carrier (Chang, 1966).

However, OFDM is considered a new digital modulation technique which consists of transmitting a data stream on several carriers instead of using only one carrier (Athaudage and Jayalath, 2004). The general concept of OFDM was first introduced in 1971 but during the last decade, with the development of Digital Signal Processors (DSP), the applications of OFDM have become visible. Moreover, OFDM is mainly used on wideband transmissions. It is also suitable for transmissions in the frequency selective channels. Such a situation is met especially in multipath environments.

Now a days, the applications of OFDM find a place in most of the following high data rate wideband transmissions: In audio and television broadcasting (DAB and DVB) where usually high data rate transmissions are required in multipath environment. In wire line transmission where Asymmetric Digital Subscriber Line (ADSL) transmits the data at a very high rate on copper wire lines. However, the problem here is that characteristics of the line are unknown and they may change among users. In wireless LAN networks with HiperLAN/2 standard where transmissions occur at a very high data rate (~10 Mb sec^{-1}) in an indoor environment, (e.g., strong multipath environment).

Like any other systems, OFDM has its own advantages and disadvantages (Han and Zhang, 2009). The main drawback of OFDM is the high Peak to Average Power Ratio (PAPR) that affects the system as addressed by many previous researchers. Therefore, the current study proposed clipping and filtering for different modulation techniques to reduce this high PAPR in order to enhance the performance of the OFDM system. This proposed solution is discussed throughout this study from the results of simulation and test in the MATLAB program.

Corresponding Author: Fadhil M. Aswad, Department of Electrical, Electronic and Systems Engineering, Faculty of Engineering and Built Environment, National University of Malaysia (UKM), 43600 Selangor, Malaysia

The OFDM technique divides the total bandwidth into many narrow sub-channels and sends the data in parallel (Weinstein and Ebert, 1971). It has various advantages such as high spectral efficiency, immunity to impulse interference and frequency selective fading without having a powerful channel equalizer. Yet, as previously stated, one of the major drawbacks of the OFDM system is the high PAPR. The issue or problem of the high PAPR is created by the wide number of independent modulated sub-carriers in the OFDM signal. This makes it impossible to send such peak amplitude signals to the transmitter without reducing the peak. Therefore, this requires a reduction of the high peak amplitude of the signals by using the clipping technique prior to transmission (Frenger and Svensson, 1996).

On the other hand, the clipping method is considered a non-linear action. So, using filter after clipping is recommended to reduce the noise and the distortion caused by the clipping method. Thus, this needs evaluating the performance of the OFDM system after using the Clipping and Filtering (CF) technique to determine or measure the effect of this method on the OFDM performance for the different Quadrature Amplitude Modulation (M-QAM). Therefore, the aim of this study is to design the OFDM transceiver including FFT (Fast Fourier Transform) and IFFT (Inverse Fast Fourier Transform), mapping (modulator), serial to parallel and parallel to serial converter in order to reduce the main drawback of the OFDM system represented by its high PAPR. To achieve this, this study proposed using the CF method. The purpose of using filter after clipping was to reduce the noise that happens after clipping directly. This was performed using a different modulation technique, M-QAM. This was intended to observe the effect of the CF method on the OFDM system for the different M-QAM as the novel idea of the current study. In other words, this was to evaluate the performance of the OFDM system for a different M-QAM before and after using the CF method which was used to reduce the high PAPR before transmitting the actual OFDM signal in the transmitter side.

Literature review

A review of research on OFDM and PAPR: OFDM is defined as a very attractive technology which is being used in many high speed applications nowadays (e.g. IEEE 802.11ad, LTE-A etc). Many previous studies have highlighted the advantages and disadvantages OFDM and how to optimize this technique because of the high PAPR. Many researchers have addressed this high PAPR as main drawback of OFDM. So, this study provides a review of previous related research in this area.

The clipping method is based on clipping time domain signal limitation according to the spatial equation. This also depends on the Clipping Ratio (CR) but clipping produces signal distortion that results into adjacent channel emission. However, this unwanted effect can be removed by using a low pass filter of clipping signal and this operation should be repeated several times to obtain an acceptable reduction of the high PAPR (Urban and Marsalek, 2007). The interleaving method is based on the idea of creating multiple OFDM signals by bit interleaving the input bit sequence. The easiest way to execute such interleaving is using matrix interleaves data by combining both methods: the CF method first followed by interleaving to achieve a good reduction of the PAPR. Yet, this method is disadvantaged for it needs side information transmission.

By comparing this method to other methods such as coding, Selected Mapping (SLM) and Partial Transmit Sequence (PTS), the CF is considered the simplest and most efficient method that can reduce the high PAPR. Therefore, in this research, we proposed a new technique to improve the CF filtering method in reducing the PAPR (Deng and Zhong, 2008). Figure 1 shows the old clipping method based on the CR equation in the time domain.

It is clear from the block diagram that there are series of the operation in the OFDM systems to obtain an acceptable reduction of the high PAPR, but it will cause both types of noise: in- band and out-of-band noise, thus causing a degradation of the BER performance. This is because of the in-band clipping noise which cannot be filtered. So, repeating clipping and filtering several times is expected to enhance the BER performance. To remove the iterative out-of-band components, Jean Armstrong proposed that the clipped signal could be filtered through the use of forward DFT followed by IDFT.

Figure 2 show the proposed algorithm using filtering by Hanning window instead of the out- of- band points nulling to improve the first algorithm in reducing the high PAPR. This shows that the smaller the clipping ratio is, the better the BER performance becomes. This is even better than the first algorithm.

According to Juwono and Gunawan (2009), they propose Huffman coding combined with Clipping and Filtering (CF) for the high PAPR reduction. This operation is carried out by using 52 subcarriers as input and QPSK modulation. This proposed the system of Huffman coding as source coding and the CF in this system to reduce the PAPR because Huffman coding assigns fewer bits for frequently occurred symbols and more bits for seldom occurred symbols. Therefore, the additional multicarrier signals for the same phase will be reduced and finally, the PAPR reduction achieved was about 7 dB.

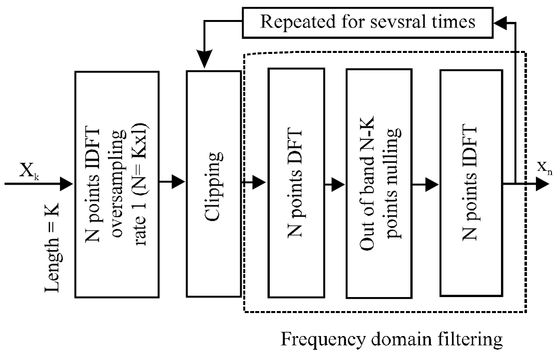

Fig. 1: Block diagram of the clipping method

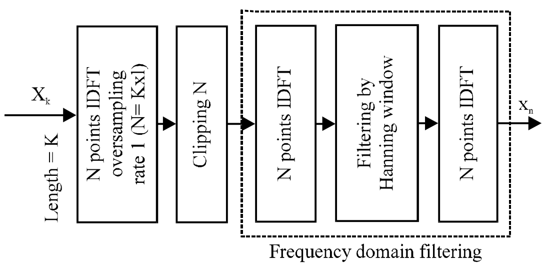

Fig. 2: Block diagram of the proposed technique

In Iwasaki and Higuchi (2010), the proposed method was used for pre-coding the OFDM-Multiple Input Multiple Output (MIMO) to reduce the high PAPR based on the CF method. This was performed by adding the same interference power from conventional clipping and filtering to each of the transmission stream. MIMO channels are beneficial in enhancing the achievable user data rate. In other words, they enhance the frequency as well as the efficiency. The combination of OFDM and MIMO is a very promising transmission scheme for future communication systems.

This method encloses the interference power applied to the streams when the sum capacity is controlled by the capacity of the streams that experience good channel conditions. In addition, the PAPR reduction produces interference due to the degradation of the achievable capacity of the stream. Such method is due to the reduction of the PAPR = 8 dB.

As found in Sharma *et al.* (2011), the technique for reducing the high PAPR in OFDM system was proposed by modifying the Iterative Amplitude Clipping and Filtering (IACF). This modification was achieved following several steps. The first step represents clipping the original signal in the time domain according to its equation. The second step is concerned with repeating this process many times to gain the desired result. The simulation result from this process shows that the proposed method achieved better PAPR reduction as compared to the conventional amplitude clipping method. Optimized Iterative Clipping and Filtering (ICF) is a widely used to reduce the PAPR. For instance, in a previous study, this optimized ICF method used optimal filter for each iteration that minimized the current OFDM symbols to the desired ones. This method replaced the rectangular filter in the classic ICF method. Furthermore, the simulation results show that the proposed method could reduce the PAPR to an acceptable level after only 1 or 2 times of iterations (Wang and Luo, 2011).

Albdran *et al.* (2012), the researchers compared the performance of OFDM and the Single Carrier (SC). Their study showed that both techniques have some advantages and disadvantages but OFDM is better than the SC because it is used for high data rate and it achieves high efficiency of bandwidth. Yet, its main drawback is the high PAPR which can be overcome using various techniques such as clipping technique, coding technique, probabilistic technique and so on. Therefore, in their study, those researchers used the clipping technique to reduce the PAPR and their result obtained from the simulation test shows that the performance of OFDM was better than that of the SC since it reduced the PAPR more at lower CR.

Previous research proposed several PAPR reduction techniques in the OFDM system. Raajan *et al.*, (2013), the researchers conducted a study comparing among three reduction techniques: the Amplitude Clipping and Filtering (ACF), the SLM and the Partial Transmit Sequence (PTS) with the aim of identifying which one would have a higher performance than the other two techniques. This comparison among the three techniques indicates each one of these three techniques has it is own algorithm and equations to reduce the PAPR in the OFDM system. Based on the result from the comparison, it was found that the performance of the ACF was the best in terms of information while the SLM and the PTS did not have an effect on the records. As a result of the assessment curve of the SLM and PTS performance, it was concluded that the PTS was the most efficient technique among the three techniques in reducing the PAPR in the OFDM system.

OFDM is a very important method to transmitting information especially in this era because the world has become a small village and as a result, the need for broadband communications including voice, data and multimedia has been rapidly increasing through the internet and mobile devices in addition to the revolution of the communication field. All these have contributed to an increase in research competition in this field to overcome the obstacles (Slimane, 2007).

From the above literature, since research has been conducted continuously to overcome the main drawback in the OFDM system related to the high PAPR, there are many methods used for decreasing this drawback and enhance the performance of the system as to obtain the best information transmission. Such above methods used in previous studies differ according to the requirement of the arrangement and are reliant on variety of aspects.

MATERIALS AND METHODS

System model of the proposed CF technique: This section discusses the methodology of the study that was adopted in the current study to design and simulate OFDM that would solve the problem or issue of the PAPR in this system. Moreover, this study describes the algorithm used in this study to solve the problem of the high PAPR in the OFDM system in particular, the use of the CF method or technique and observation of the system performance after clipping and filtering for the different modulation technique, M-QAM.

Mathematical CF Model: The major drawback in the OFDM system is the high PAPR and so, the simplest way to reduce this drawback is amplitude clipping. In fact, this was performed for the actual OFDM signal in the transmitter side in the time domain by clipping the signal according to its amplitude to the average value. Although this technique has several disadvantages, the BER performance could be affected negatively due to the in-band distortion as well as the out-of-band radiation which usually appears while using the clipping technique that could disturb the adjacent channel (Fig. 3).

So, we used filtering after clipping to decrease the appearance of the out-of-band radiation. The below the equation shows clipping the signal before transmission: The signal c(t) is the baseband modulated one with the carrier frequency:

$$c(t) = \begin{cases} x(t) & \text{for } x(t) \leq A \\ A & \text{for } x(t) > A \end{cases} \quad (1)$$

where the clipping level is denoted by (A) and the CR can be represented as follow:

$$CR = \frac{A}{\sigma} \quad (2)$$

where the RMS value of the OFDM signal is denoted by σ and $\sigma = \sqrt{N/2}$ it is well known that for the pass band OFDM signal (Albdran *et al*., 2012).

The simulation CF model: While the main purpose of this research was to reduce the PAPR in the OFDM system first, it also aimed to evaluate the performance of the system after using the clipping CF method to reduce the PAPR by using the different modulation techniques M-QAM. This can be the main novel idea of the present study. For the research design used in this study, the current study used or utilized the test driven approach for system development and testing. So, in this study, our working environment is situated or contextualized in MATLAB programming and coding.

System description: This reserach includes three main parts through the OFDM, this appear clearly in OFDM flow chart in Fig. 4.

Different Modulation techniques (M-QAM): The baseband modulation orders are range of three values (16,

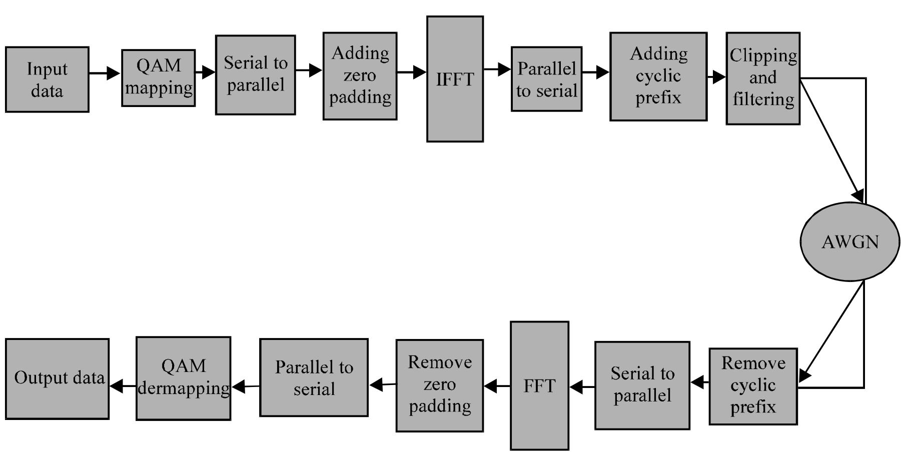

Fig. 3: OFDM block diagram

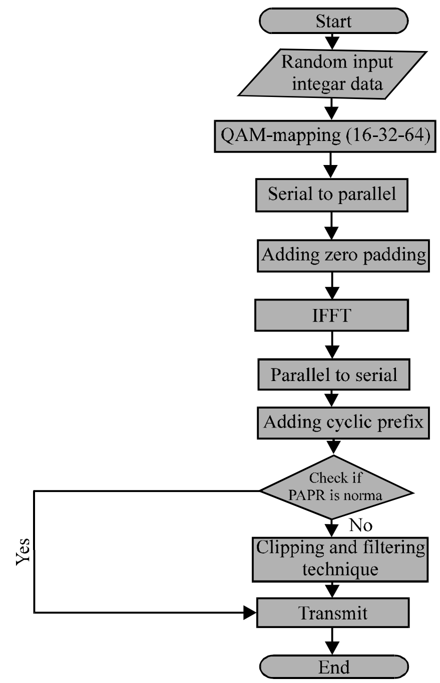

Fig. 4: OFDM flow chart

32 and 64), this represents the number of data constellation in the transmitter and receiver side. So, it is used.

Clipping and Filtering method (CF): This is the main algorithm in this research to show its effect on OFDM performance and it's related to the previous condition.

OFDM performance: The last part in system description is OFDM performance, this represent the main objective in this research. The main issue is to see the performance of the OFDM and the effect of clipping and filtering, what happen if we remove the filter from the system and the effect of this on system performance, finally the comparison between these two cases on the system performance.

Parameters specifications: In this study we have assumed OFDM signal with the following specifications:

- M-QAM signal constellation = 16, 32 and 64
- No of data points = 256*2*64
- Clipping Ratio (CR) = 0.13
- Number of subcarriers (N) = 256
- Length of cyclic prefix (CP) = 64

RESULTS AND DISCUSSION

This study discusses and analyzes the results of the simulation model proposed as mentioned. It also discusses the result obtained from observing the

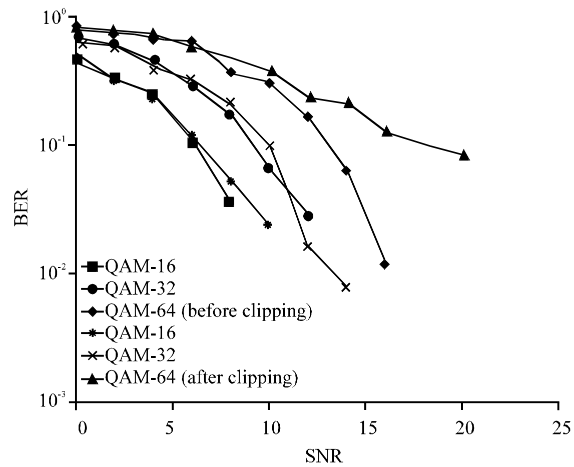

Fig. 5: BER vs SNR for OFDM for the different M-QAM (without filtering)

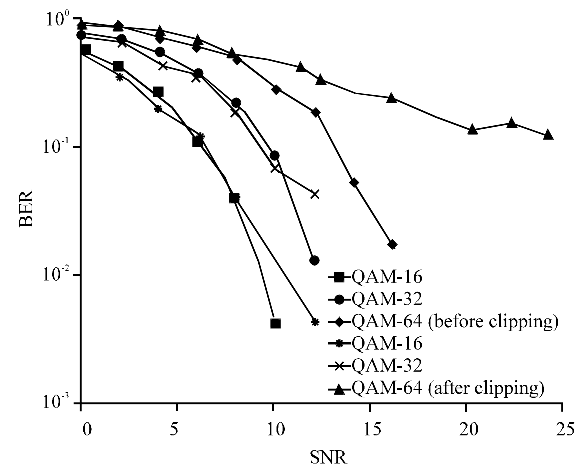

Fig. 6: BER vs SNR for OFDM for different M-QAM (with filtering)

OFDM performance after clipping to reduce the high PAPR. This use of filter after clipping aimed to measure the effect of the M-QAM on the OFDM performance.

The OFDM performance was evaluated in this comparison by using the MATLB code but let us first define what BER is. Simply, it is the effect of bits divided by the overall number of the transmitted bits over time intervals to see the differences among them. From Fig. 5 above, there are six curves: three of them represent the performance before clipping and the other three represent the performance after clipping. Using the clipping method only to reduce the high PAPR increased the noise because of the non-linear action of clipping and it negatively affected the OFDM performance (in-band distortion and out-of- band radiation). This is evident as shown in Fig. 5 for (16-QAM, 32-QAM and 64-QAM). So, to overcome these drawbacks, we used the filter after clipping to generate an acceptable result as seen in Fig. 6.

Figure 6 shows the result obtained by filtering after using the clipping method. As seen from the result for (16-QAM and 32-QAM), both BER and noise were reduced, but for 64-QAM, it can be noticed that while there is a reduction only in BER, the enhancement in the noise is too small or minor. This is an important result of the present study by which we achieved the research objectives.

CONCLUSION

In this study, the research objective was achieved through designing the OFDM transceiver. However, since its major drawback is the high PAPR which has been addressed by previous research and reduced using many techniques, in this study, we selected the clipping method according to our problem statement in this project. This is because this method could cause in-band distortion or out- of- band radiation which could destroy the signal or disturb the adjacent channel. On the other hand, clipping is regarded a non-linear process that may lead to a significant distortion and increase the noise and errors. Because of this, it was necessary to use the filter after clipping. The performance result reported in the present study is acceptable because there is no increase in the system noise and errors after clipping and filtering. Thus, it can be concluded that this research led to PAPR reduction at a lower CR, a result underlyingthe effect of the proposed CF method on the OFDM system for three M-QAM (16, 32 and 64). This also indicates that the BER and SNR were enhanced after this process. Using the filter in this research contributed to reducing the noise and distortion resulted from clipping in the transmitter.

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